A Visual Analytics Platform for Tracking Orthopedic Implant Kinematics on High-Speed X-Ray During a Simulated Sideways Fall

Jade Levine, Emily Bliven, Pierre Guy, Anita Fung, Ingmar Fleps, Benedikt Helgason, Peter A. Cripton

Hip fracture is a debilitating injury with a high rate of morbidity, mortality, and chronic illness. Previous studies have found that the mortality rate associated with this injury is 12 to 36% within one year of hip fracture.[1] In addition, those that do survive live with decreased mobility, often relying on others for their primary care. The majority of hip fractures in the elderly occur through an impact to the greater trochanter of the femur due to a sideways fall from a standing position.[2] As orthopedic implants are becoming increasingly common, the biomechanical properties at the interface between the bone and implant, specifically during events such as falls from standing, are presently unknown.[3] With the instance of mortality for periprosthetic fracture having a similar rate to that of hip fracture, understanding the mechanics of periprosthetic fracture is advisable for the design of future implants.[4] This study will investigate the kinematics of an orthopedic implant during a simulated sideways fall impact using highspeed x-ray video analysis.

We used an inertial-based testing apparatus developed during a previous study[5] to simulate a sideways fall impact from standing height using cadaveric pelvis-femur constructs. Specimens were instrumented on the impacting side with a generic orthopedic implant typically used for hip fracture fixation. A custom bilateral high-speed x-ray system[6] was used to capture impact phenomena from each trial. The x-ray videos are then exported to XMALab for undistortion and calibration using images of a calibration object taken prior to initiation of the experiment.

After each experiment, the undistorted images were uploaded to a visual analytics platform developed specifically for this experiment. Here, the kinematics of the implant and bones will be tracked throughout the duration of the fall. Using known dimensions of the implant and the principles of roentgen stereophotogrammetry, the visual analytics tool outputs the translation and rotation of the implant with respect to the bone in three-dimensions, giving a global view of the implant kinematics. This allows examination of the mechanics of periprosthetic fracture by studying the motion of the implant within the bone with respect to impact force-time data and fracture propagation.

Preliminary tests done with a surrogate femur (Sawbones) implanted with a generic orthopedic implant have allowed bone-implant motion in this configuration to be captured using high-speed x-ray.[7] The captured implant kinematics will be used to further understand the biomechanics of periprosthetic fracture in cadaveric specimens during a simulated sideways fall. Understanding the kinematics at the bone-implant interface may inform the design of future orthopedic implants to mitigate the potential for periprosthetic fracture. This has the potential to reduce the likelihood of periprosthetic fracture by increasing the implant's ability to protect the bone during a common injury scenario.